

Full-Scale Sloshing Impact Tests—Part I

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This paper describes the first full-scale tests on a real membrane containment system subjected to the action of breaking waves representative of sloshing impacts in LNG tanks. The waves were generated in a water flume using a wave focusing method. The tests were carried out within the Sloshe! project, which is described in several accompanying papers. This paper focuses on describing the test method, the experimental setup and the post processing of the data collected in 110 tests; it explains how the project goals were translated into the design of the test setup and the instrumentation. Then it describes an extensive qualification of the data acquisition system and sensors. Emphasis is on the sensors developed within the project, such as pressure gauges and a novel optical sensor capturing the last stage of the sloshing impact. The test programme and some preliminary results are summarised. Conclusions are given regarding system performance, data quality and the use of data for achieving the project goals.

INTRODUCTION

In this paper, Brosset, Mravak, Kaminski, Collins and Finnigan (2009) introduce the Sloshe! experiment, designed to collect full-scale data describing sloshing impacts and associated structural response. This data set will be used to verify different assessment methods of membrane-type containment systems subjected to sloshing.

Conventional sloshing assessments of new membrane LNG carriers traditionally follow the comparative approach that is based on small-scale model testing, numerical simulations and over 40 years of successful operating experience of LNG carriers. Model testing provides the maximum loads, based on the statistical analysis of measured pressures. The response of the containment system to these loads is numerically simulated and checked against different limit states.

However, with the filling level limitation on the current fleet, experience is lacking to support comparative methods for partially filling cargo tanks. To move forward, the industry is developing a methodology to assess membrane systems by a direct comparison of the loads and the structural capacity. To develop such a methodology, MARIN recognised the need for full-scale validation already back in 2003 (Fig. 1).

Sloshe!, a confidential joint industry project, was organised. The scope of work included full- and large-scale tests being carried out by MARIN, developments of simplified numerical methods being carried out by Bureau Veritas, and validation studies being carried out by individual consortium members.

This paper describes full-scale sloshing tests successfully carried out by MARIN in the Delta flume operated by Deltares. Malenica, Korobkin, Ten, Gazzola, Mravak, De-Lauzon and Scolan (2009) described simplified numerical methods they have developed. Maguire, Whitworth, Oguibe, Radosavljevic and Carden (2009), and Wang and Shin (2009) described validation studies undertaken by LR and ABS, respectively.

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KEY WORDS: Sloshing, full-scale testing, large-scale testing, LNG, membrane containment systems, NO96, pressure sensors.

TEST METHOD

As stated in the Introduction, the sloshing assessment of a membrane LNG vessel has traditionally been carried out using small-scale model tests and additional numerical simulations. The questions are:

- How close to reality are these experimental and numerical models?

- What are the hydroelastic and scale effects?

In order to answer these questions full-scale data are needed, with simultaneous measurements of fluid dynamics and structural response. But the question was:

- How to obtain full-scale data?

So, first of all the following wish list was formulated about the way the full-scale data should be collected:

- in full scale
- with a real containment system
- with sloshing impacts such as those in LNG membrane tanks
- with many sloshing impacts
- with measurable impact conditions and structural response
- with controllable and repeatable sloshing impacts
- in cryogenic conditions
- with LNG

Then, the different concepts listed in Table 1 were proposed and evaluated. None of these concepts was accepted because of the reasons given in the table. Following that, it was concluded that the complete wish list cannot be satisfied, and it was agreed to release the list's last 2 requirements and to carry out the full-scale testing with water. In this way the allowance for cryogenic conditions was shifted to the material testing and associated acceptance criteria. The different behaviour of water with air at ambient pres-

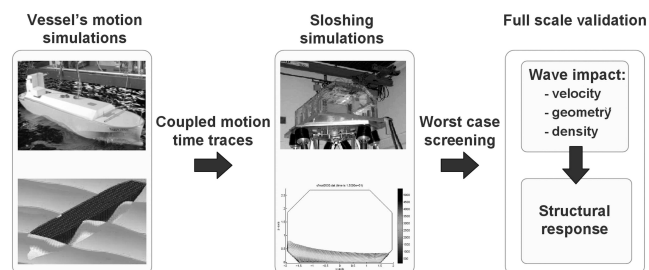


Fig. 1 Sloshing assessment and role of Sloshe! project